EVALUATING A LOW PRESSURE FOG NOZZLE PROGRAM FOR THE ROCKY MOUNT FIRE DEPARTMENT

EXECUTIVE DEVELOPMENT

BY: James M. Stallings
District Fire Chief
Rocky Mount Fire Department
Rocky Mount, North Carolina

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ABSTRACT

The selection of fire nozzles that utilize an adjustable fog spray should be based upon the careful consideration of many factors. Gallon-per-minute capability, reach, pattern effectiveness, ease of maintenance, cost, and gallon-per-minute requirements are among the performance and budgetary issues that should be examined. The problem was the Rocky Mount Fire Department had no comprehensive method of evaluating fog nozzle performance in order to make recommendations for future purchases.

The purpose of this research paper was to study the concept of low pressure fog nozzles and determine their applicability to the RMFD. Information will be examined related to nozzle performance, compliance with applicable consensus standards, organizational acceptance, and comparisons with other departments. Historical and evaluative research will be used to answer the following research questions:

1. What are the performance comparisons of low pressure nozzles with conventional fog nozzles?
2. Are there other departments that have used comprehensive performance testing methods for fog nozzles?
3. What would be the budgetary considerations for replacing the current fog nozzle inventory with low pressure nozzles?
4. What resistance to change might be expected?

The procedures used to complete this research consisted of a literature review of books, periodicals, and reports. Other procedures were: 1) A fire department survey instrument to indicate related practices of other fire departments. 2) A historical review

of the RMFD nozzle program was conducted. 3) The department initiated in-house nozzle testing to generate data.

The results of this research included the substantiation of the fact that most fire departments do not conduct comprehensive fog nozzle testing. Also, there are organizational theories that are applicable to initiating an organizational change that are useful when initiating a transformation within the fire department. The research results also indicated a need for development of a comprehensive nozzle program within the RMFD.

TABLE OF CONTENTS

INTRODUCTION

The Rocky Mount Fire Department has always been perceived by its members to be progressive and willing to move forward with operational issues. The department had not hesitated to seek information, specifications, and products from manufacturers when examining new tools, equipment, apparatus, and facilities. Several types and brand names of nozzles were purchased and placed in service in an effort to evaluate performance through actual on-scene fire operations and direct feedback from the firefighters. These types of equipment performance appraisals were very subjective due to observer bias, technical knowledge possessed by the observer, and misconceptions of fog nozzle performance. Over the course of many years, the well-intentioned efforts resulted in a dozen different configurations of gallon-per-minute capabilities, size, construction materials, and nozzle manufacturers. Each fire apparatus held an inventory of nozzles that were not of the same make and had varying performance and operating features. Apparatus operators were faced with the demands of providing proper nozzle pressure and gallon flow to meet a wide variety of nozzle operating requirements. This situation compounded the task of determining accurate fire ground hydraulics calculations by increasing the amount of data the apparatus operator had to reference which, in turn, increased the likelihood of errors. Of greater significance was that the department still had not decided which nozzle to use to standardize apparatus nozzle inventory. Additionally, the department had no means of making in-house repairs to damaged nozzles. Units had to be sent to the manufacturer which resulted in long down-time and increased operating costs.

The problem was the Rocky Mount Fire Department had no comprehensive method of evaluating fog nozzle performance in order to make recommendations for future purchases. Additionally, no program existed for maintenance and repairs.

The purpose of this research paper was to concentrate on the concept of low pressure fog nozzles and determine their applicability to the RMFD. Specifically, the research narrowed the focus of the nozzle evaluation program and provided direction in that area.

Historical and evaluative methods of research were employed for this project. Research consisted of review of literature, surveys of other departments, and departmental field testing and evaluation of new nozzle equipment from several manufacturers under controlled conditions.

The research questions were:

1. What are the performance comparisons of low pressure nozzles with conventional fog nozzles?
2. Are there other departments that have used comprehensive performance testing methods for their fog nozzles?
3. What would be the budgetary considerations for replacing the current fog nozzle inventory with low pressure nozzles?
4. What organizational theories might apply related to resistance to changing from conventional fog nozzles to low pressure units?

BACKGROUND AND SIGNIFICANCE

The Rocky Mount Fire Department is located in the upper coastal plain region of the state of North Carolina approximately 50 miles east of the capital city of Raleigh. The RMFD currently employs 118 personnel in the Operations Division, 6 personnel in the Fire Prevention Division, 3 personnel in Fire Training, and 2 personnel in the Administrative Division. All job positions are staffed with paid, full-time employees. The fire department operates under a Mayor/Manager/Council form of government.

The background for this research project began with the realization that there was no evaluative method being used to determine the specifications for purchasing fog nozzles. In the past, departmental research for the various nozzle products that were available was limited to studying brochures and listening to sales pitches from manufacturers. No departmental testing and evaluation under controlled circumstances was initiated since there was no equipment available in the department to perform testing of the fog nozzles. The department did utilize a standard pitot gauge for measuring the performance of solid bore nozzles, but this method is ineffective for measuring the flow from fog nozzles. As a whole, the department did not realize that there may be discrepancies in the perceived performance of the fog nozzles in use as compared to actual performance testing. Manufacturer claims were the only reference for analyzing nozzle performance.

In 1996, four members of the department became interested in the characteristics of nozzles and fire hose and formed an informal group that began to independently research the feasibility of low pressure fog nozzles as well as performance characteristics of various brands of fire hose. After discovering the potential advantages of the low pressure nozzles, the group presented a report with preliminary findings to the fire chief..

From this initial briefing, the chief announced the formation of the Fire Streams Committee. The committee was charged with researching products, making recommendations, and preparing Standard Operating Guidelines related to hose lay configurations, nozzle testing and maintenance, and creating reference charts for fire ground hydraulics calculations. A small initial operating budget was established for the purchase of testing equipment.

The organizational impact resulting from the original presentation to the fire chief was that the efforts by a group that has common interests can be directed toward the potential of having a positive effect on the operations of an organization. Individual interests can be meshed with others to form a cohesive group that shares common interests and goals that align with departmental objectives.

The Fire Streams Committee consisted of three district fire chiefs from the Operations Division, the District Chief of Fire Training, two fire captains, two fire apparatus operators, and one firefighter. The representation of several levels of the rank structure was desired and was somewhat successful; however, member participation was limited by work schedules and different levels of interest in the project. All the members except the original four were essentially appointed by the chief to serve on the committee.

The probable future impact on the RMFD operations is considerable. The effectiveness of water delivery for fire extinguishment is expected to be a positive aspect of the project. It is anticipated that a comprehensive nozzle testing program will be initiated to validate manufacturer's claims when new nozzles are being considered for purchase. Also, an in-house nozzle maintenance program will likely be initiated that will have a positive effect on nozzle performance and longevity. Downtime required for repairs should be shortened because of not having to send the unit back the manufacturer for refurbishing.

Justification for this study comes from several areas. The organization could benefit from recommendations related to operating fire hose equipped with low pressure nozzles. Studies indicate that many career departments are experiencing dwindling numbers of personnel due to budget cut backs, labor negotiations, and the assignment of fewer firefighters to apparatus. Volunteer organizations have also suffered from the same dilemma (Fornell, 1991). The reduction of labor has caused departments to research methods of better utilization of available manpower. The use of low pressure fog nozzles may contribute to more efficient use of the numbers of firefighters that are available on the fire ground.

The organization would also realize the need to rewrite the departmental guidelines for applying fire ground hydraulics. The previous guide had been in use since 1986. It was used in general departmental training and as part of promotional testing for apparatus operator. Since 1986, additional changes had taken place with regard to new nozzle equipment and the removal of obsolete or terminally damaged units. The RMFD hydraulics guide was in need of updating to reflect the types of nozzle equipment that was in service.

The greater benefit to the RMFD is the realization that good ideas come from those who are closest to the problem. The four people who originated the notion of researching low pressure nozzles were personnel assigned to first-line fire fighting positions. They assumed a position of having a group concept that united them toward a common goal. This translated into self direction for the group that motivated them to take action. In effect, the group reached out for …" a bit of wisdom, a new idea, or a new concept, that stretches them, and gives them answers to their own self-generated problem " (Brouwer, 1965).

This research is being conducted in accordance with the requirements of the Executive Development section of the National Fire Academy's Executive Fire Officer Program. In Chapter 4 of the course material, students were introduced to the phases of innovation and individual creativity and potential blocks to organizational creativity. This section of the instruction applies to the research project.

LITERATURE REVIEW

<u>What are the performance comparisons of low-pressure nozzles with conventional fog nozzles?</u>

Conventional nozzles, for the purpose of this research, are those that flow their rated capacity at 100 p.s.i. nozzle pressure and low-pressure nozzles are those that flow their rated capacity at 75 p.s.i. nozzle pressure.

All spray nozzles must meet minimum standards set forth in NFPA 1964, Standard for Spray Nozzles (National Fire Protection Association, 1998). This reference lists the design requirements, construction materials, test methods, and compliance testing for spray (fog) nozzles. The 100 and 75 p.s.i. nozzles fall under the minimum standards listed in NFPA 1964. The standard states that all spray (fog) nozzles must be marked with the rated pressure, rated flow rate, manufacturer, model designation, all other markings required by this standard. All fog nozzles must flow their rated capacity at the rated nozzle pressure (National Fire Protection Association, 1998).

Fornell (1990) found that, for interior attack with fog nozzles, low-pressure nozzles offer several advantages over conventional fog nozzles that require a nozzle pressure of 100 p.s.i.

1. Less nozzle reaction force is generated.

2. Less air mixed with the fire stream which tends to increase the stream's penetration into high heat areas.

3. Water droplets are larger in the spray pattern and tend to not vaporize into steam as easily.

4. Due to the lower operating pressure, the fire hose is not as stiff which enhances maneuverability.

5. Fixed gallonage, low-pressure nozzles are not as expensive, are more durable, and firefighters are more easily trained in their use.

6. Apparatus pump operators will flow the rated gallonage rather than make attempts to reduce the reaction force by reducing pump pressure.

Side-by-side tests of 100 and 75 p.s.i. nozzles found that low-pressure nozzles exhibit less nozzle reaction force making them much easier to handle. Also, the tests showed that the low-pressure nozzles produces larger water droplet size which allowed more water to travel farther toward the fire before converting to steam. To extinguish fire, both types of nozzles must meet the minimum flow requirements, also called "critical rate of flow" (Clark, 1995).

The important factors of fog nozzle performance are flow characteristics, pattern control, and volume control (Fornell, 1991). The author suggests that various construction features of spray nozzles, such as spinning teeth at the discharge point, are not as important as actual performance on the fire ground.

Nozzles have three main functions. They control water flow, provide reach for the water stream, and a nozzle will create a shape, or pattern, of water spray (Akron Brass Company, 1996).

The Chicago Fire Department conducted tests to compare their standard conventional nozzles with low-pressure nozzles. The effect of the tests showed that low-pressure nozzles could deliver more water on the fire than the standard nozzles they were using before. Additionally, the low-pressure nozzles reduced firefighter stress by reducing the nozzle reaction force. CFD also discovered that the fixed gallonage low-pressure nozzles had fewer internal moving parts and predicted that maintenance costs would be lower for the low-pressure units compared with automatic or adjustable gallonage nozzles. The best way to determine which nozzle suits the needs for any department is to take time to perform extensive evaluative testing of several types of nozzles (O'Donnell, 1995).

The use of piezometers and flow meters will provide the easiest and most effective method of checking gallon-per-minute flow and nozzle pressure. The formula for determining flow for fog nozzles is expressed as $NR = GPM \times \sqrt{NP} \times .0505$, where NR is nozzle reaction in force/pounds, GPM is gallons per minute flowing, NP is nozzle pressure, and a constant of .0505. This formula was developed by Akron Brass (see

Appendix A). Tests show that there is a significant difference in the nozzle reaction force between the 100 and 75 p.s.i. nozzles (Fornell, 1990).

Some of the literature review was obtained from sources that may not be considered current; however, the information contained in those sources should be considered relevant to the research because they relate to standard mathematical formulas or hydraulic theory.

In summary, the literature research indicated that the basic operational concepts of low-pressure nozzles and conventional nozzles are essentially the same. All spray (fog) nozzles must meet minimum standards for construction, testing, and performance. This researcher found through the literature review that independent nozzle testing by several large fire departments and individuals resulted in very similar outcomes. The effects of reduced nozzle reaction force from the low-pressure nozzles was indicated as the most significant performance feature as compared to the conventional nozzles. Additionally, the increased effectiveness derived from larger water droplet formation and deeper penetration into heated areas was noted. There was universal agreement in the literature research for fire departments to conduct their own extensive testing to determine which nozzle will best suit the water application requirements and performance needs of each organization.

Are there other departments that have used comprehensive performance testing methods for fog nozzles?

Various fire departments across the United States have used performance testing for their fog nozzles (Fornell, 1991). Los Angeles Fire Department, San Francisco Fire

Department, and Chicago Fire Department have attempted to address flow/personnel issues by finding improvements in water flow hardware.

Captain Gil Moreno, head of San Francisco's Bureau of Equipment, said his department was concerned with a single issue that led to the testing of new hose and fire nozzles. "We wanted maximum flow using the least amount of people." (Fornell, 1991).

The Los Angeles Fire Department began an extensive personnel/flow testing program in the early 1980s that compared nozzle reaction generated by various nozzles and pressures. Battalion Chief Claude Creasy and his evaluation group found that the most effective streams that two fire fighters could handle were produced by lowering the nozzle pressure on a standard combination fog nozzle (Fornell, 1990). Fornell (1990) writes that, in 1984 after working with nozzle manufacturers, Los Angeles purchased nozzles that would flow their rated capacity at 75 p.s.i. of nozzle pressure.

The Chicago Fire Department also conducted performance testing on a number of different nozzles to facilitate the a new fire attack program they called "quick water" (Fornell, 1991).   The author describes in detail how department officials found that they could flow more water by using 1 ¾" handheld hose lines with high-flow combination nozzles as compared to using 1 ½" hose line and conventional nozzles. Chicago Fire Department determined a target flow of 150 g.p.m. for interior fire fighting efforts. At the suggestion of a nozzle manufacturer, they purchased fog nozzles that required 75 p.s.i. of nozzle pressure at a flow of 150 g.p.m.

David Fornell (Fornell, 1990) describes nozzle evaluative testing that he was involved with in his own department.   He is a Lieutenant and Training Officer of the Beckerle & Company Hose Company of the Danbury (CT) Fire Department. Fornell

(1990) describes how they used portable flow meters and special line gauges in his own department to evaluate three fixed gallonage nozzles set by the manufacturer to flow 150 g.p.m. at 75 p.s.i. of nozzle pressure. They found that low pressure nozzles exhibited the advantage of less nozzle reaction force and produced larger water droplet size. Mr. Fornell is the published author of the *Fire Stream Management Handbook.*

A survey instrument was used to determine if other fire departments used evaluative nozzle testing (see Appendix D). Representatives from 25 departments from across the United States were asked if their department had ever conducted comprehensive testing for their nozzles (see Appendix C). The departments' membership ranged from a low of 20 personnel to a high of 2800. 18 questionnaires were returned. Of these 18, there were three departments that answered affirmatively on the question of conducting comprehensive nozzle testing. Two of the departments that have used comprehensive nozzle testing are in Florida and one is in North Carolina.

<u>What would be the budgetary considerations for replacing the current fog nozzle inventory with low-pressure nozzles?</u>

The replacement of a fire department's nozzle inventory with new equipment requires a large amount of capital outlay depending, of course, on the size of the department and the specific nozzle requirements. If a large, metropolitan department decides to complete the replacement within one budget year, the costs could be staggering, but could be accomplished if funds had been set aside in prior budget years for that purpose. Smaller departments would likely need to implement a planned replacement program that would span several years.

In most cases, the replacement plan would have to be reviewed by a city council, board of directors, or some other form of governing body. The department would provide sufficient justification for the requested expenditures. The governing body would review the budget request and determine if the funds would be made available.

Several companies offer products related to spray nozzles used for fire fighting purposes. Brochures and catalogs offer descriptions of a wide range of variations of nozzles performance, specifications, and prices. A review of sales catalogs from two major nozzle manufacturers indicates a wide range of prices for a wide range of nozzle selections. For the purpose of this literature review, only the prices of low pressure nozzles for hand lines will be compared to show the estimated cost per unit.

What literature might be applicable when attempting to institutionalize an organizational change in traditional operational procedures?

Organizations must adapt to change to be more effective. Frederickson (1980) identified one way an organization can address the subject of change:

> …change is now so rapid that the only way organizations can be responsive is to develop criteria by which they can judge effectiveness and then to institutionalize procedures by which changes, and often fairly rapid changes, can be made so as to make the organization capable of being responsive (Frederickson, 1980).

Leaders of an organization must provide a catalyst of commitment for the success of changing the attitudes and habits of individuals and groups. If any change is to occur, leaders must support that change. Relationships between groups and their leaders are important. Leadership effectiveness in a group is not based on the formal position of the leader. Instead, it is based upon the perception of what the leader can do for the group in return for the leader's acceptance by the group (Gortner, Mahler et al. 1989).

A plan or strategy is needed to implement an organizational change, such as operational procedures or standard operating guidelines. Strategies for organizational operation determine how an organization will achieve its goals. It provides a basic pattern of resource allocation. In *The Effective Public Manager,* Cohen (1988) discusses how strategy:

> …attempts to delineate the resources that will be used to pay for specific activities designed to accomplish specific objectives. Strategy formulation begins with the identification of objectives and the determinations of methods for reaching objectives (Cohen, 1988).

Cohen (1988) also describes that it is difficult to have influence over an organization's agenda without strategy. If we are fortunate, and at the same time do not have a strategy, we may even end up looking like we know what we are doing. "There are a lot of stupid, but lucky, people out there with excellent, though wholly undeserved, professional reputations" (Cohen, 1988).

An organization must consider that procedural changes come from using qualitative and quantitative techniques that are commonly referred to as a systems analysis. Systems analysis is just one tool in helping organizations determine the need for changing organizational structures or processes. Experience and personal insight are also important factors (Gortner, Mahler et al. 1989).

Organizations must have leaders that can create conditions that lead followers to partnerships. These partnerships work cohesively to embrace change for the good of the organization. They are committed to continuous quality improvement. They look for ways to reduce wasted time and energy, to balance personal interests with the interests of others, and discover and share a common purpose ((The National Fire Academy 2000).

PROCEDURES

This research project employed historical and evaluative research methodology to (a) examine the performance comparisons of low pressure nozzles with conventional fog nozzles, (b) examine other departments to determine if comprehensive performance testing methods for their fog nozzles is widely practiced, (c) evaluate the budgetary considerations for replacing the Rocky Mount Fire Department's current fog nozzle inventory with low pressure nozzles, and (d) examine applicable literature The procedures used to complete this research included a fog nozzle performance evaluation by the Rocky Mount Fire Department, a survey of practices in other departments, cost projections for department-wide conversion to low pressure fog nozzles, and a literature review.

Fog Nozzle Performance Evaluation

The City of Rocky Mount Fire Department Fire Streams Committee conducted a series of evaluative performance testing of fog nozzles (Stallings, 1998). The purpose was to compare the various performance characteristics of conventional combination fog nozzles with low pressure fog nozzles, evaluate the current inventory of fire hose nozzles, and to make recommendations based upon test results. A Fire Streams Committee was formally organized with representation from the ranks of Fire Fighter, Fire Apparatus Operator, Fire Captain, and District Fire Chief.

The committee conducted tests on Akron® and Elkhart® fog nozzles to evaluate several areas of operational characteristics. In-house testing scenarios were developed by the committee to evaluate manufacturer claims of the performance of their respective fire nozzles. Manufacturer data was compared to actual field-testing performed by the committee.

The Fire Streams Committee used the department's fire training facility to conduct evaluative scenarios to generate data. Individual engine companies provided input by participating in the scenarios and by completing a written evaluation form on each test.

The evaluation form consisted of questions relating to:

1. Nozzle operational characteristics, such as operation, pattern, maneuverability, reach, control, and overall impression.

2. The number of personnel required to operate and control the fire stream.

Fire Department Survey

A survey instrument was developed to ascertain if other departments utilized comprehensive performance testing methods for their fog nozzles. The survey was also designed to assess if other departments utilize low pressure nozzles or conventional combination fog nozzles.

The survey consisted of a combination of questions that asked the respondents to answer in the open-ended method and the simple yes/no format. The questions related to (a) number of personnel, (b) average number of fire related responses per year, (c) use of fog nozzles on initial attack lines, (d) required nozzle pressure for in-service units, (e) variations from the use of 100 p.s.i. nozzle pressure, (f) comprehensive testing, and (g) if a nozzle maintenance program was being utilized (see Appendix D).

The survey respondents consisted of class participants in the National Fire Academy's Executive Fire Officer Program's class on Executive Development. Each class member completed a written survey instrument (see Appendix E).

Typically, the respondent selection for fire department surveys is based upon similarities with the survey initiator relating to number of personnel, area of response coverage, number of stations, budget, etc. In contrast to this perceived norm, the survey respondents utilized for this research project represented fire departments from across the country that varied in size, budget allocation, and other resources.

Nozzle selection and use is a common practice among most fire departments regardless of size. A survey that asks questions about nozzles is applicable to any fire department. The author believes, for the type of survey information requested, that the responses received adequately fulfills the intent of the survey.

Budgetary Considerations

The Fire Streams Committee prepared budgetary information relating to the projected cost of replacing the current fog nozzle inventory with low pressure fog nozzles. Quotes were received from several manufacturers that could supply fog nozzles that could meet the specifications set forth by the committee. Several options for implementing the replacement program were reviewed. The department could budget to replace all the units within one fiscal budget year or a stepped replacement method that would take several years to complete.

Literature Review

A literature review was initiated at the National Fire Academy's Learning Resource Center (LRC) during June 2000. The literature review was continued at the Rocky Mount Fire Department reference library between June 2000 and September 2000.

The literature review consisted of references from magazines, trade journals, consensus standards, and textbooks. The germane basis of the related information is included in the Literature Review section of this research project.

Assumptions

The procedures used in this research project were based upon basic assumptions. First, the supposition was made that all the authors referenced in the literature review were unbiased and objective in the research information they provided. Second, it is assumed that the data obtained from the nozzle test scenarios by the Rocky Mount Fire Department Fire Streams Committee is a reasonably accurate appraisal of nozzle performance characteristics. Third, it was implied that the survey respondents provided accurate information relative to the survey instrument questions and that the questions were answered objectively.

Limitations

The limitation that affected this research project was time. The initiation of a replacement program for fog nozzles is a time consuming effort that requires a large amount of research to measure the potential effectiveness of an operational change. Follow-up interviews with participants in the test scenarios would have enhanced monitoring the effectiveness of the new low pressure nozzles. Most of the test scenario participants have had an opportunity to utilize the low pressure nozzles on actual emergency incidents, but the Fire Streams Committee has not been afforded the time to conduct objective feedback sessions.

Definition of terms:

Control – The physical effort required to regulate the nozzle while flowing water. Some factors that may influence control are weight and whether the nozzle is equipped with an auxiliary handle.

Conventional Combination Nozzles – Fog nozzles that operate at a required nozzle pressure of 100 pounds per square inch. This category of fog nozzles usually has an operating feature that allows the nozzle operator to adjust the flow of water by turning a selector for various gallon-per-minute settings.

Initial Attack Lines – Hose lines attached to a fire pumper used in the first attempts to place water on the fire.

Low Pressure Nozzle – Generally speaking, a fog nozzle that operates at a required nozzle pressure lower than 100 pounds per square inch.

Maneuverability – A term used to describe the ability of the nozzle operator to move the nozzle to various positions. Hand placement and position of operating controls are also part of this definition.

Operation – This term describes the general operating characteristics of the fog nozzle from a mechanical point of view. It includes the physical effort needed to open and close the shutoff valve and the physical effort needed to change the pattern from straight stream to full fog.

Overall Impression – The opinion and general comments received from the nozzle operator based upon participation in the nozzle testing scenarios.

P.S.I. – Pounds per square inch of water pressure.

Pattern - A term used to describe the physical characteristics of the water spray as it leaves the fog nozzle relating to compactness of the stream, size of the water droplets, and consistency of the spray configuration.

Reach – The distance the stream of water travels from the time it leaves the nozzle until it attains the point of application.

Required Nozzle Pressure – The nozzle pressure recommended by the manufacturer and applicable standards. The nozzle should flow its rated capacity of gallons-per-minute at a specific nozzle pressure.

RESULTS

What are the performance comparisons of low pressure nozzles with conventional fog nozzles?

Side-by-side evaluation of low pressure and conventional fog nozzles was conducted by the members of the Fire Stream Committee. Engine company personnel participated in the scenarios and were asked specific questions concerning the performance of the nozzles. The test participants were cautioned to be objective in providing responses in an attempt to reduce bias or personal opinion.

Six specific areas of nozzle performance were tested and compared. Each nozzle was rated on these criteria and assigned a numerical designation, with 1 being the highest rating:

- Control
- Reach
- Pattern
- Operation
- Maneuverability
- Overall

SCOPE OF TESTING

The first test procedure involved advancing an 1 ¾” hose line into the burn building (see Appendix B, Figure 1). The line was brought into the front room of the burn building, relocated to the rear room, then exited along the route of entry. Water was flowing using the straight stream pattern when the lines were positioned at the first room.

No water was flowing at the time of egress. The straight stream was used because it created the most nozzle reaction force that could be anticipated.

The test method for the second evolution (see Appendix B, Figure 2) was a scenario for flowing water from a hose line and advancing it along a straight line for a distance of approximately 50 feet. The line was then retracted back to the starting point with the continuation of the water flow. All nozzles for this test were set on straight stream and flowed the rated gallons per minute. The point of impact for the fire stream was concentrated on a stationary target to help evaluate the effects of maneuverability. The objective for these two tests was to compare the performance of two types of nozzles under equal simulations.

TEST METHODS

All tests were carried out by individual engine companies that normally work with each other on a daily basis. The test teams consisted of three personnel. Each team was responsible for advancing their hose and taking up slack while operating the nozzles used in the test.

Test One

For the test using the 100 p.s.i nozzle and the 75 p.s.i. nozzle, the team advanced the hose line to the front room of the first floor of the fire department burn building at the training facility (see Appendix B, Figure 1). There the nozzle was opened and the hose line advanced into the room while water was flowing. Then the hose was backed out and advanced to the rear of the building toward a closet at the back corner. The team then shut off the water supply and backed out of the structure.

Each team was asked to evaluate the performance of the nozzle based upon the criteria of control, reach, pattern, operation, maneuverability, and an overall rating. The observations were recorded on a prepared form by a fire stream committee member.

Test Two

A separate test area was set-up with a stationary nozzle test stand. Distances for reach and width were measured and marked to provide for easy measurement during testing. A supply line with piezometers and a digital flowmeter were attached to the test stand from a fire department pumper. Each nozzle was attached to the stand and the manufacturer's recommended nozzle pressures were applied. The following characteristics were obtained from each nozzle test:

A. Gallons - per - minute

B. Nozzle reaction

C. Straight Stream reach

D. 90 degree fog pattern width

E. 30 degree pattern reach

Description of Tests

Test for 100 p.s.i. Nozzle – 200' of 1 ¾" fire hose with the 100 p.s.i. , adjustable gallonage, fog nozzle. The gallon per minute selector was set at 150 g.p.m. with a nozzle pressure of 100 p.s.i. as recommended by the manufacturer. The pump pressure was 140 p.s.i. Determination of pump pressure was based upon previous tests on friction loss in this particular hose. The line was manned by a three-person engine company who were dressed in full protective clothing without self contained breathing apparatus.

Test for 75 p.s.i. Nozzle - 200’ of 1 ¾” fire hose with the 75 p.s.i., single gallonage, fog nozzle. The single gallonage nozzle flows 175 g.p.m. with a nozzle pressure of 75 p.s.i. as recommended by the manufacturer. The pump pressure was 135 p.s.i. Determination of pump pressure was based upon previous tests on friction loss in this particular hose. The line was manned by a three-person engine company who were dressed in full protective clothing without self contained breathing apparatus.

Nozzle Test Results

Appendix B, Figures 3 – 8 illustrates bar graph comparisons of the nozzle testing results. The assessment of the performance of the nozzles that flowed in the 150/175 gpm range show that the low pressure nozzles (75 psi) were rated superior to the 100 psi nozzles in all categories except the comparison on reach. Reach was greater for the 100 p.s.i. nozzle due to the higher nozzle pressure.

Appendix B, Figure 9 illustrates the differences in nozzle reaction force for the 75 and 100 p. s. i. nozzles flowing the same gallons per minute. Two tests results are shown with the gallons flow set at 150 and 200 gallons per minute. Using the hydraulic formula to determine nozzle reaction force, the low pressure nozzle will be consistently lower throughout the gpm range due to the lower nozzle pressure required.

Are there other departments that have used comprehensive performance testing methods for fog nozzles?

A survey instrument was developed to ascertain if other departments utilized comprehensive performance testing methods for their fog nozzles (see Appendix E). The survey was also designed to assess if other departments utilize low pressure nozzles or conventional combination fog nozzles. A letter was sent to the respondent departments soliciting assistance with the survey (see Appendix D).

The survey consisted of a combination of questions that asked the respondents to answer in the open-ended method and the simple yes/no format. The questions related to (a) number of personnel, (b) average number of fire related responses per year, (c) use of fog nozzles on initial attack lines, (d) required nozzle pressure for in-service units, (e) variations from the use of 100 p.s.i. nozzle pressure, (f) comprehensive testing, and (g) if a nozzle maintenance program was being utilized.

Twenty five surveys were delivered to the respondents. The return rate was 68% with 17 completed surveys being returned.

Number of Personnel

The survey respondents consisted of a representation from small fire departments to large metropolitan organizations. The number of paid personnel ranged from 15 to 2,000 depending on the size of the individual departments. Some departments enlisted volunteers, but these numbers were not used in the assessment of number of personnel. The average number of paid personnel for all survey respondents was 258.

Average Number of Fire Related Responses per Year

The annual average of the number of responses was included in the survey to indicate the potential opportunities for the departments to utilize fog nozzles. The responses ranged from a low of 1000 fire related responses per year to a high of 500,000. The average fire related responses for all survey respondents was 32,639. This average was significantly skewed by the volume of fire calls experienced by a large metropolitan fire department (500,000). The significance of the average fire calls for all respondents is a moot point for the purpose of the survey.

Use of Fog Nozzles on Initial Attack Lines

The survey was designed to obtain information on nozzles from the various survey participants; therefore, only the departments that use fog nozzles on initial attack lines contributed to this section of the results. Of the 17 respondents, 94% of the departments indicated that they utilize fog nozzles exclusively on attack lines.

Nozzle Pressure used for In-Service Nozzles

Eighty seven percent of the departments that use fog nozzles on initial attack lines indicated that they use the standard 100 p.s.i. nozzles..

Variations from the use of Standard Combination Fog Nozzles

Six percent of the respondents indicated the use of nozzles that require a nozzle pressure other than the standard 100 p.s.i. combination nozzles. These departments use nozzles that require a operating nozzle pressure of 75 p.s.i.

Comprehensive Testing

Survey respondents were asked if their department has ever conducted comprehensive nozzle performance testing. Of the 17 respondents, 13% indicated that they had conducted nozzle testing.

Nozzle Maintenance Program

The presence of a nozzle maintenance program was indicated in 58.8% of the survey respondents. The level of maintenance varied from simple inspections to annual performance testing and calibration of gallon-per-minute flow.

What would be the budgetary considerations for replacing the current fog nozzle inventory with low pressure nozzles?

At the time of the initiation of research into low pressure fog nozzles, the Rocky Mount Fire Department operated with a total of nine fire pumpers that utilized fog nozzles. One of these pumpers was a reserve unit that was fully equipped and maintained in a ready state for use as a front line pumper. Two of the nine apparatus were aerial devices. One was a 85’ articulating boom and the other was a 75’ ladder. The inventory of fog nozzles on these apparatus consisted of all 100 p.s.i. combination nozzles.

The Fire Streams Committee conducted inquiries directed toward obtaining costs for converting all the 100 p.s.i. combination fog nozzles to low pressure (75 p.s.i.) fog nozzles. Appendix E illustrates the costs that would be incurred for each of the nine pumpers.

Maintenance Program

An associated cost of improving the nozzle program was the creation of a nozzle maintenance program. The department wanted to protect the investment made in the low pressure fog nozzles to ensure proper operation. Also, annual testing and calibration would be an important function for proper operation. Factory training for two personnel would be provided as well as a parts inventory for completing repairs.

Maintenance Program Costs

Factory training for two personnel		$1000.00
Spinner rings and service kits		$750.00
	Total	**$1750.00**

The total cost of replacing the 100 p.s.i. nozzles with 75 p.s.i. nozzles and the nozzle maintenance program is $16,230.00. This represents a sizeable budgetary issue. The plan for the implementation of the program is to set up a replacement schedule over a period of time. The costs would be spread over a five year period.

What resistance to change might be expected?

The research helped to identify several potential indicators of resistance to change in an organization. As expected, there was initially resistance among some members in the organization in relation to changing from the traditional 100 p. s. i. fog nozzles to the low pressure 75 p. s. i. units. After these members participated in the gathering of quantitative data, many were able to realize the benefits of using the low pressure nozzles. Research identified in the literature review supported the technique of gathering data, or system analysis, to help determine a need for procedural change.

Some resistance to procedural changes came from management, not because of a lack of understanding the benefits of the new program, but rather from a budget perspective. This program required a significant amount of money to fund the initiation and completion of the change to the low pressure nozzles and the nozzle maintenance program. A certain amount of commitment from management to provide the necessary budgetary funding was essential for the program's success. The program and the theoretical benefits had to be "sold" to management in order to show proper justification for the expenditure of the money. Management fully supports the program and has been able to provide for the phasing in of the purchase of new equipment.

Resistance to change in the fire service is typical of any emergency service organization whose history is rooted in tradition. The idea of changing just to be changing is generally not very well accepted in the fire service. Those organizations who continue operate in a particular manner because "that's the way we have always done it" face real challenges to even acknowledge that there may be a better way to accomplish things or that a better tool may be used to do the job faster and safer.

Resistance to change can also be fostered by the organization's leaders. The research indicates that leaders must provide the catalyst for the success in changing attitudes and habits of the members (Gortner, Mahler et al. 1989). In our case, the leaders within the formal supervisory ranks supported the low pressure nozzle program and were able to have a significant influence on the perceptions of the followers.

DISCUSSION

The National Fire Protection Association Standard, NFPA 1964, Standard for Spray Nozzles sets minimum standards for the performance of fog nozzles (National Fire Protection Association, 1998). Design requirements, construction materials, test methods, and compliance testing is the same for 100 p. s. i. nozzles as it is for 75 p. s. i. nozzles. All the nozzles purchased for the initiation of the low pressure nozzle program were marked by the manufacturer with the rated pressure, rated flow rate, manufacturer, model designation, and all other markings required by NFPA 1964. The Fire Streams Committee made a commitment to assure that all nozzles used by the Rocky Mount Fire Department are compliant with NFPA 1964. To benefit from a legal standpoint, it was advantageous for the department to purchase only compliant nozzles.

Tests performed by Fornell (1990) and Clark (1995) indicated that the lower nozzle reaction force generated by low pressure nozzles makes the nozzle much easier to handle. The tests also showed that the low pressure nozzles produced much larger water droplet sizes that allowed the water to travel farther toward the seat of the fire before vaporizing into steam. The test conducted by the Fire Streams Committee also indicated that the low pressure nozzles were noticeably easier to handle and control as compared to the 100 p. s. i. fog nozzles (see Appendix B, Figure 7). The mathematical computations for determining nozzle reaction force supported the indication of easier handling characteristics. In fact, the committee found that one less firefighter could be used to control the nozzles during the tests while flowing both 150 and 200 gallons per minute. This allows for the completion of additional tasks on the fire ground by the firefighter who is no longer needed to assist in the control of nozzle flow.

Fornell (1990) suggests that the use of piezometers and flow meters is the most effective method of measuring actual water flow through the nozzle and nozzle pressure. The Fire Streams Committee was able to purchase several in-line gauges, or piezometers, as well as a portable flow meter with digital readout (Stallings, 1998). These instruments proved absolutely crucial in the accuracy of the nozzle testing that was performed. The testing was done with high quality and accurate measuring devices that were factory calibrated. These testing instruments will be utilized as part of the nozzle maintenance program to assure that the fog nozzles are performing efficiently.

The Chicago Fire Department conducted comparison tests between conventional nozzles and low pressure nozzles (O'Donnell, 1995). They discovered several advantages of the low pressure nozzles. The critical point of this part of the literature was apparent when there were conclusions presented that strongly suggested that any department needs to conduct their own evaluative testing to determine which nozzle meets the specific needs of the department. The Rocky Mount Fire Department did just that. We talked with several vendors and obtained specification catalogs to educate ourselves of the specifics of nozzle design and performance requirements. Then, we obtained testing equipment to compare our findings with manufacturer claims. This evaluative testing proved critical in determining and deciding which nozzle to use for the specific needs of our department.

Perspective related to the potential effects of introducing a change in our organization was gained through literature review of several references (Cohen, 1988), (Frederickson, 1980), (Gortner, Mahler et al. 1989), and (The National Fire Academy, 2000). The Fire Streams Committee expected resistance from mainly the “old school” members; however, with commitment from the leadership of the Rocky Mount Fire Department and a strategy to implement the change, the low pressure nozzle program was accepted and has proven to be effective. The committee provided hard evidence through the evaluative testing that demonstrated to the members the advantages of the low pressure nozzles. This system analysis stood as proof of determination to develop a product that would be beneficial to the department.

RECOMMENDATIONS

The Rocky Mount Fire Department had no methods or means of evaluating nozzle performance in order to make informed decisions concerning the purchase of new nozzle appliances. The implementation of our nozzle program has greatly enhanced the ability of the department to be proactive in relation to nozzle purchases. It is recommended that the Rocky Mount Fire Department continue to perform evaluative and performance testing on all nozzles under consideration for purchase.

Additionally, all nozzles in service should be performance tested annually to assure that the rated flow and rated nozzle pressure are being met. In order to accomplish organized performance testing, data forms are recommended for development to track nozzle performance testing. Each nozzle should be assigned a number or some other type of inventory control marking to aid in making sure that all nozzles are tested. Individual data sheets should be used to record performance results. Any maintenance that is performed on the nozzle can also be entered on the data sheet. It is recommended that a computer program be used to assist with record keeping and statistical reports for the nozzle performance testing. Microsoft Access© is a suitable database program that should meet the requirements of a nozzle performance record keeping system.

The Rocky Mount Fire Department should develop an in-house nozzle maintenance program. Repairs to the nozzles can be made much quicker than returning the units to another repair facility or the manufacturer. The maintenance program should include a sufficient quantity of parts to expedite repairs. Two persons should be trained and certified to perform the maintenance. These persons would submit a budget that includes monies for parts and equipment. A small repair site should be established, perhaps at one of the fire stations or the apparatus maintenance shop. A regular schedule of nozzle inspection and maintenance should be developed and followed.

Continuous improvement of monitoring nozzle performance should be enhanced by developing a short survey to be used after incidents involving the use of the nozzle. The survey should list yes/no questions related to droplet pattern, penetration, steam conversion, handling characteristics, and operating mechanics. Also, nozzle performance can be discussed during post incident critiques.

It is strongly recommended that departments purchase testing equipment, such as piezometers and flow meters, to evaluate the performance of nozzles before purchasing. Always compare actual testing with manufacturer claims to validate or invalidate nozzle performance. Departments should look at the intended use of the nozzle to be sure that purchases will not be a waste of money on a product that will not meet performance expectations.

Departments considering a nozzle performance program should consider using a survey instrument to discover data related to other departments' experience with a particular nozzle product. The survey should be adequately comprehensive to provide the needed information for the requesting organization. Written surveys should be date driven for return of the information. Surveys should be directed toward the person in the respondent department who can provide the most accurate and timely information.

The purchase of new nozzles, particularly those that have different operating requirements, should be followed by department-wide training. The training should include operating characteristics and emphasis on safety issues surrounding the use of the equipment. Operating manuals should be available to each member.

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Appendices Not Included. Please visit the Learning Resource Center on the Web at http://www.lrc.fema.gov/ to learn how to obtain this report in its entirety through Interlibrary Loan.